

Reduction of solar photovoltaic resources due to air pollution in China

Supporting Information

Xiaoyuan Li^a, Fabian Wagner^{b,c,d}, Wei Peng^{b,1}, Junnan Yang^b, and Denise L. Mauzerall^{a,b,2}

^aDepartment of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544;

^bWoodrow Wilson School of Public and International Affairs, Princeton University, Princeton, NJ 08544;

^cAir Quality and Greenhouse Gases Program, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria;

^dAndlinger Center for Energy and the Environment, Princeton University, Princeton, NJ 08544;

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¹ Present address: Belfer Center for Science and International Affairs, Harvard Kennedy School of Government, Cambridge, MA 02138.

² To whom correspondence should be addressed. Email: mauzeral@princeton.edu.

SI Tables

Table S1. Grid-level impact (units of kWh/m²/day) of aerosols and clouds on point-of-array irradiance (POAI) for fixed panels (FIX). Percent impacts are calculated as the corresponding value divided by All-Sky (AS) POAI and are included in brackets.

Change of	Northern Grid	Eastern Grid	Central Grid	Northeastern Grid	Northwestern Grid	Southern Grid
Total POAI due to Aerosols	-0.73 (-13.7%)	-0.83 (-21.1%)	-0.62 (-15.9%)	-0.49 (-9.8%)	-0.48 (-8.6%)	-0.47 (-11.1%)
Total POAI due to Clouds	-1.27 (-23.8%)	-2.00 (-50.4%)	-2.34 (-59.5%)	-1.62 (-32.5%)	-1.65 (-29.6%)	-2.31 (-54.5%)
Direct POAI due to Aerosols	-1.17 (-38.9%)	-1.14 (-78.6%)	-0.83 (-57.7%)	-0.70 (-25.3%)	-0.91 (-30.4%)	-0.68 (-42.7%)

Table S2. Data type, descriptions and variables used for each dataset.

Dataset	Type	Description	Variables
NASA CERES -- SYN1deg Edition 3A	Radiation	Spatial Resolution 1° by 1°	Surface Flux of direct , diffuse and global (direct + diffuse) shortwave radiation calculated from satellite data under three atmospheric conditions: (1) All-sky , (2) Clear-sky , and (3) All-sky-without-aerosol .

Table S3. Location and Aerosol Optical Depth (AOD) Information from all 50 sites in the China Aerosol Remote Sensing Network (CARSNET) and results for the statistical comparison with AOD climatology from CERES-SYN1deg.

Site	Location			AOD _{CERES}	AOD _{CARSNET}	Bias		Root-Mean-Square Error	
	Lon.	Lat.	Alt. (m)	Mean	Mean	Mean	%	%	
Remote Sites (4 sites)									
Akedala	47.12	87.97	562	0.195	0.154	0.041	26.58	0.111	71.62
Lhasa	29.67	91.13	3663	0.137	0.094	0.043	45.55	0.088	93.73
Mt. Waliguan	36.28	100.92	3810	0.239	0.128	0.111	86.78	0.147	115.34
Shangri-La	28.02	99.73	3583	0.174	0.083	0.092	110.84	0.112	135.14
Rural Sites (24 sites)									
Dunhuang	40.15	94.68	1139	0.256	0.293	-0.037	-12.68	0.196	66.93
Ejina	41.95	101.07	940.5	0.244	0.221	0.023	10.51	0.152	68.72
Hami	42.82	93.52	737	0.226	0.221	0.004	1.98	0.151	68.48
Hotan	37.13	79.93	1374.7	0.501	0.591	-0.090	-15.31	0.184	31.12
Jiuquan	39.77	98.48	1477.3	0.287	0.277	0.010	3.73	0.187	67.72
Minqin	38.63	103.08	1367	0.308	0.344	-0.036	-10.40	0.134	38.80
Tazhong	39	83.67	1099.4	0.258	0.512	-0.254	-49.57	0.323	63.15
Wulate	41.57	108.52	1288	0.300	0.240	0.060	24.95	0.156	65.03
Xilinhot	43.95	116.12	1003	0.212	0.217	-0.005	-2.42	0.072	32.90
Zhangbei	41.15	114.7	1093.4	0.280	0.268	0.012	4.35	0.089	33.36
Zhurihe	42.4	112.9	1152	0.215	0.203	0.012	6.07	0.072	35.61
Dongsheng	39.83	109.98	1460.5	0.318	0.382	-0.064	-16.76	0.107	28.11
Mt. Gaolan	36	103.85	2161.6	0.392	0.390	0.001	0.33	0.175	44.78
Yan'an	36.6	109.5	958.5	0.402	0.308	0.094	30.56	0.139	45.21
Yulin	38.43	109.2	1135	0.343	0.318	0.026	8.09	0.125	39.27
Changde	29.17	111.7	565	0.929	0.455	0.474	104.33	0.490	107.86
Dongtan	31.52	121.96	10	0.816	0.479	0.336	70.24	0.361	75.30
Gucheng	39.13	115.8	45.2	0.566	0.534	0.032	5.89	0.197	36.81
Huimin	37.48	117.53	11.7	0.851	0.554	0.297	53.59	0.358	64.58
Lin'an	30.3	119.73	138.6	0.657	0.587	0.070	11.91	0.129	21.96
Mt. Longfeng	44.73	127.6	330.5	0.326	0.246	0.080	32.40	0.151	61.09

Mt. Tai	36.25	117.1	1591	0.774	0.249	0.525	210.75	0.535	214.84
Shangdianzi	40.65	117.12	293	0.430	0.377	0.053	14.01	0.153	40.44
Tongyu	44.42	122.87	151	0.308	0.196	0.111	56.69	0.156	79.30
Yushe	37.07	112.98	1041.5	0.559	0.457	0.103	22.48	0.174	38.21

Urban sites (31 sites)									
Anshan	41.08	123	23	0.520	0.587	-0.067	-11.37	0.171	29.21
Beijing	39.8	116.47	31.3	0.732	0.605	0.127	21.02	0.261	43.07
Benxi	41.32	123.78	183	0.520	0.760	-0.240	-31.58	0.222	29.23
Chengdu	30.65	104.03	496	0.930	0.768	0.162	21.11	0.238	31.01
Dalian	38.9	121.63	91.5	0.591	0.421	0.171	40.56	0.209	49.77
Datong	40.1	113.33	1067.3	0.324	0.419	-0.096	-22.79	0.160	38.24
Fushu	41.88	123.95	80	0.520	0.437	0.083	19.02	0.254	58.07
Hangzhou	30.23	120.17	42	0.854	0.803	0.051	6.34	0.143	17.77
Hefei	31.98	116.38	92	0.801	0.686	0.115	16.78	0.184	26.82
Kunming	25.01	102.65	1889	0.380	0.363	0.016	4.53	0.100	27.59
Lanzhou	36.05	103.88	1517.3	0.392	0.663	-0.272	-40.94	0.385	58.00
Nanjing	32.05	118.77	99.3	0.832	0.718	0.114	15.84	0.199	27.65
Nanning	22.82	108.35	172	0.643	0.678	-0.035	-5.12	0.093	13.74
Panyu	23	113.35	145	0.705	0.644	0.061	9.43	0.166	25.69
Pudong	31.22	121.55	14	0.816	0.663	0.153	23.01	0.203	30.63
Shenyang	41.77	123.5	60	0.520	0.632	-0.112	-17.68	0.189	29.94
Tianjin	39.1	117.17	3.3	0.748	0.627	0.121	19.30	0.215	34.24
Urumqi	43.78	87.62	935	0.267	0.415	-0.148	-35.67	0.310	74.77
Xi'an	34.43	108.97	363	0.718	0.734	-0.016	-2.20	0.104	14.14
Yinchuan	38.48	106.22	1111.5	0.380	0.460	-0.080	-17.33	0.219	47.55
Zhengzhou	34.78	113.68	99	0.934	0.759	0.175	23.13	0.242	31.85

SI Figures

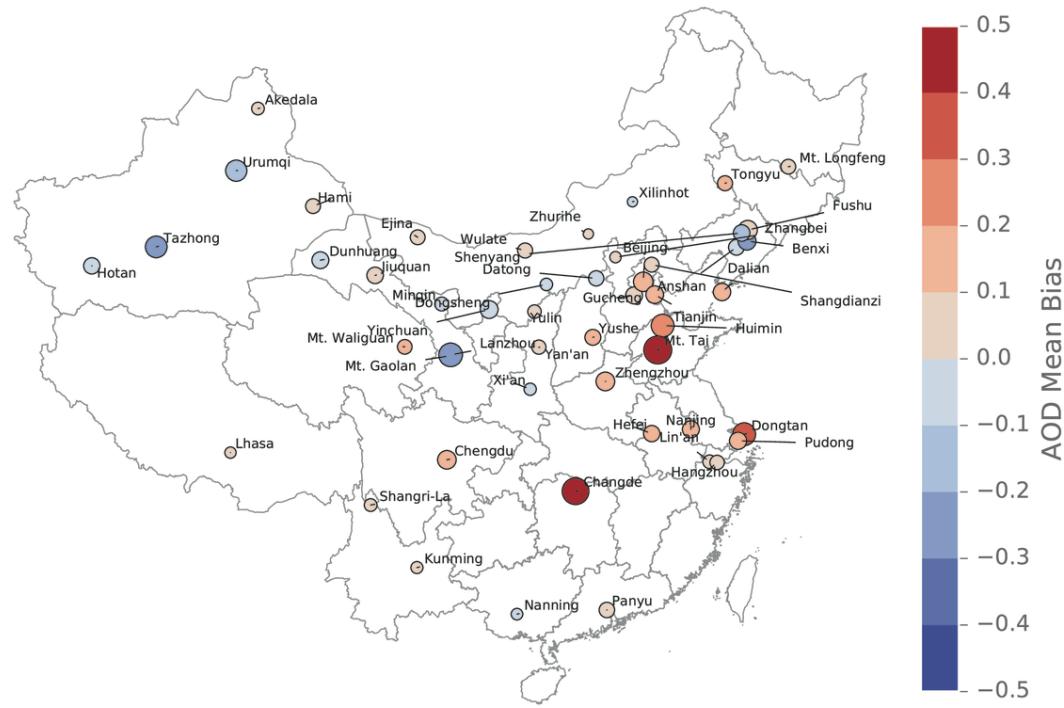


Figure S1. Comparison between AOD monthly climatology used for CERES-SYN1deg and observations from CARSNET at 50 sites in China from 2003-2014. Color represents the mean bias: CERES minus CARSNET. Root-mean-square error (RMSE) is indicated by the size of the circles. Values of biases, RMSEs, percent error, as well as the site information, are shown in Table S3.

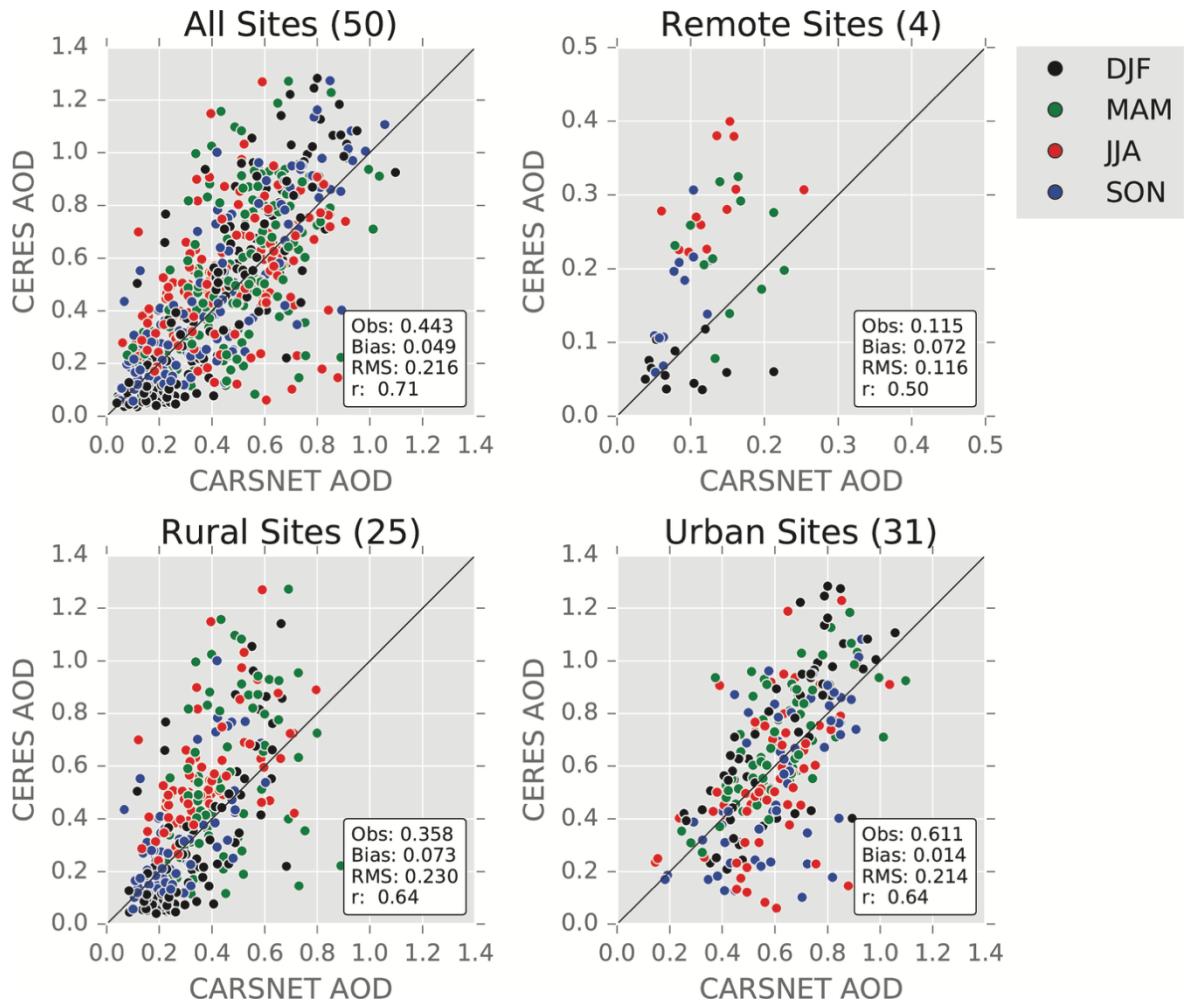


Figure S2. Comparison of monthly-mean AOD climatology between CERES-SYN1deg (2003-2014) and CARSNET (2002-2013, only available for 12-year average without data for individual years) at all 50 sites (upper left), and re-grouped into remote sites (upper right), 25 rural sites (lower left), and 31 urban sites (lower right). Each color represents mean values for a season: black marks denote December, January and February (DJF), green marks denote March, April and May (MAM), red marks denote June, July and August (JJA), and blue marks denote September, October and November (SON). Observational mean (Obs), mean bias (Bias), root-mean-square error (RMS) and correlation coefficient (r) for each category are shown in the box.

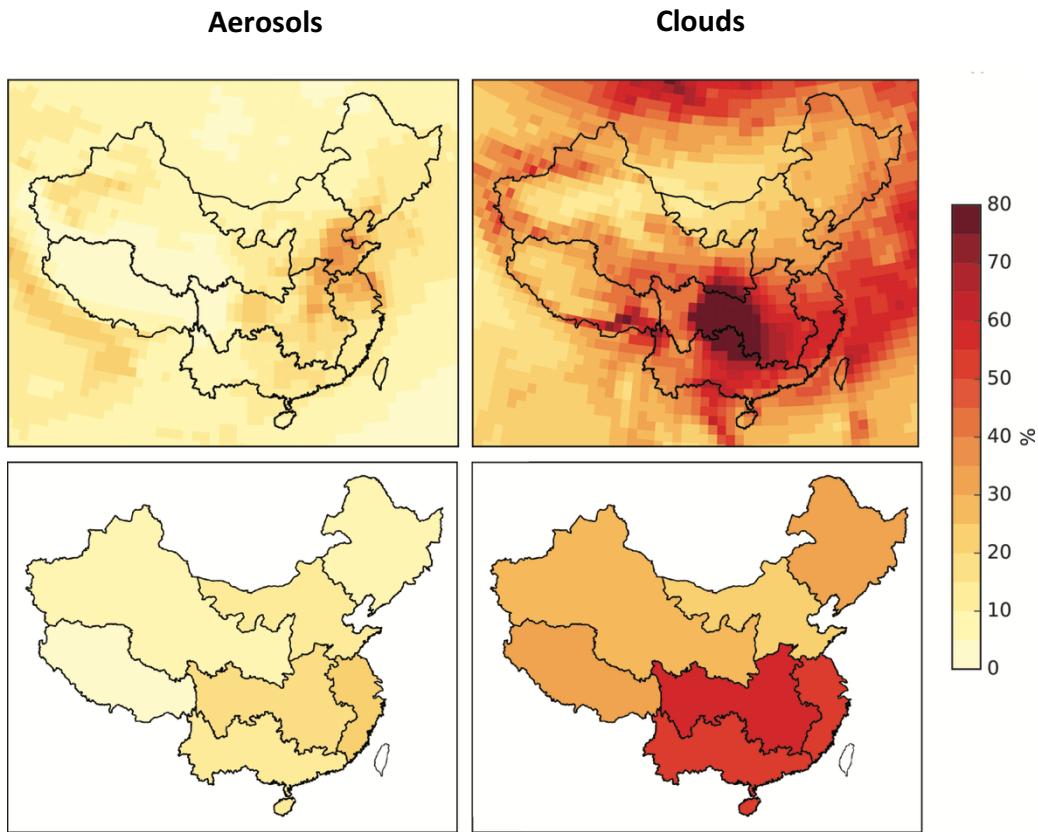


Figure S3. % Reduction of Point-of-Array Irradiance due to Aerosols and Clouds at $1^\circ \times 1^\circ$ grid-cell level (upper panels) and for each electricity grid (bottom panels). Values of grid-level reduction can be found in Table S1.

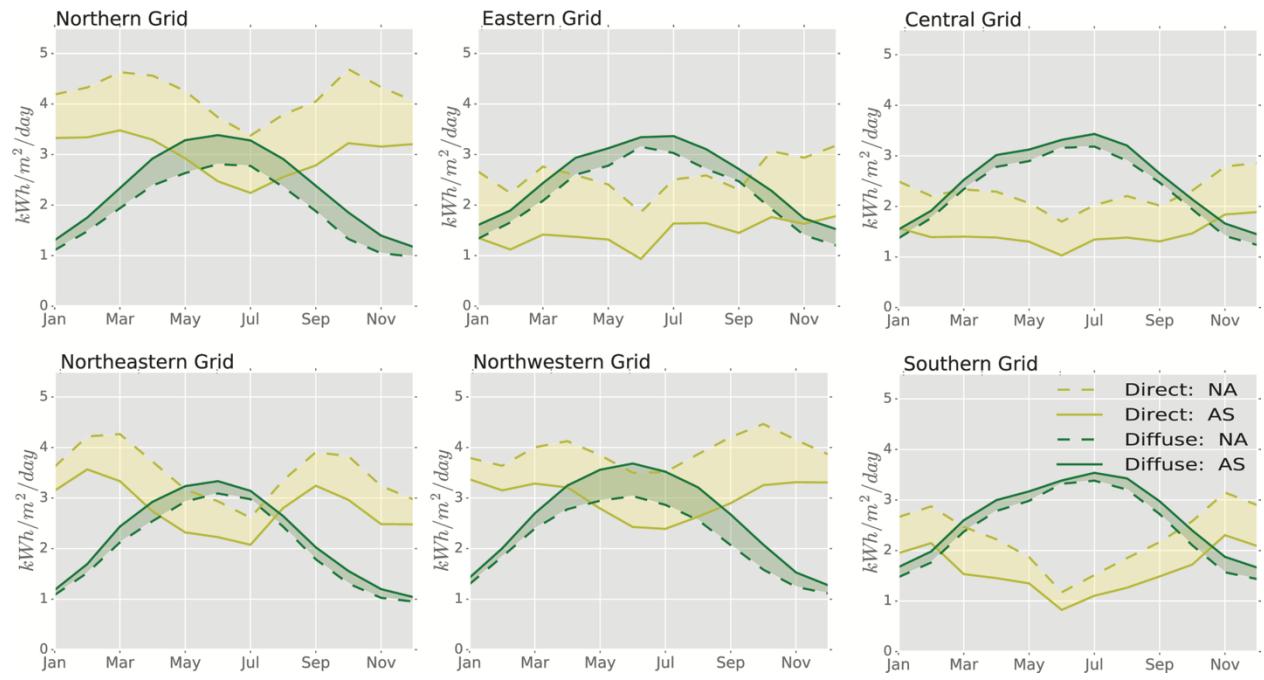


Figure S4. Seasonality of Point-of-Array Direct and Diffuse Irradiance for China's Six Electricity Grids.

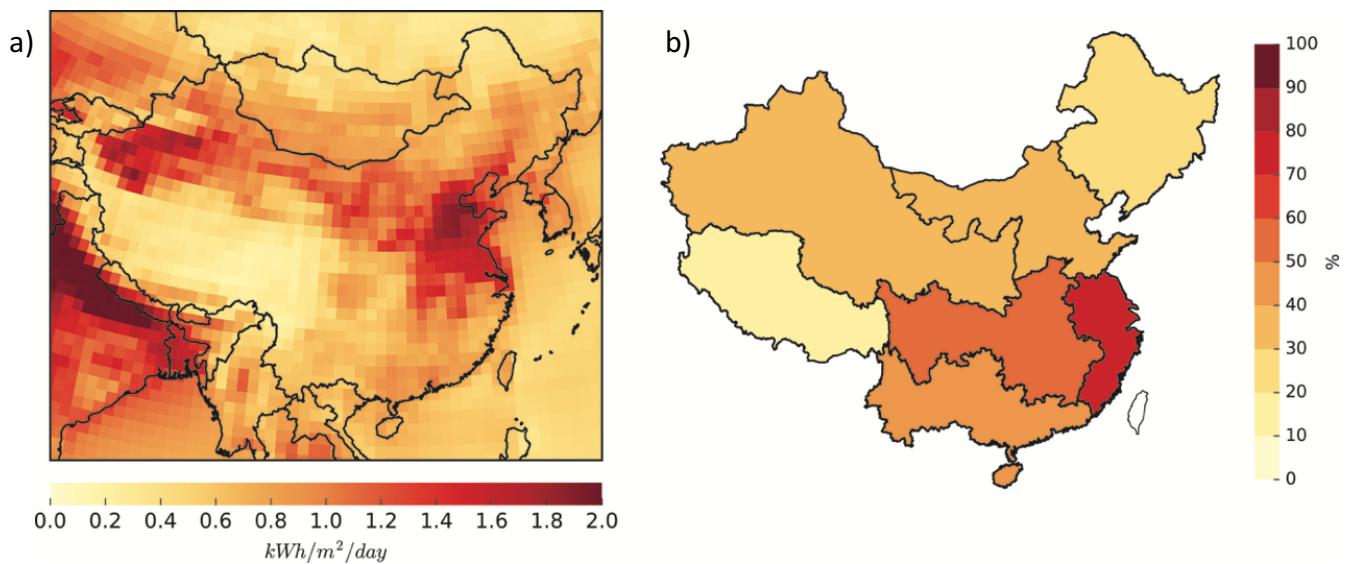


Figure S5. Reduction of Point-of-Array surface direct radiation due to aerosols: a) absolute loss; b) percentage loss. Values of grid-level reduction can be found in Table S1.

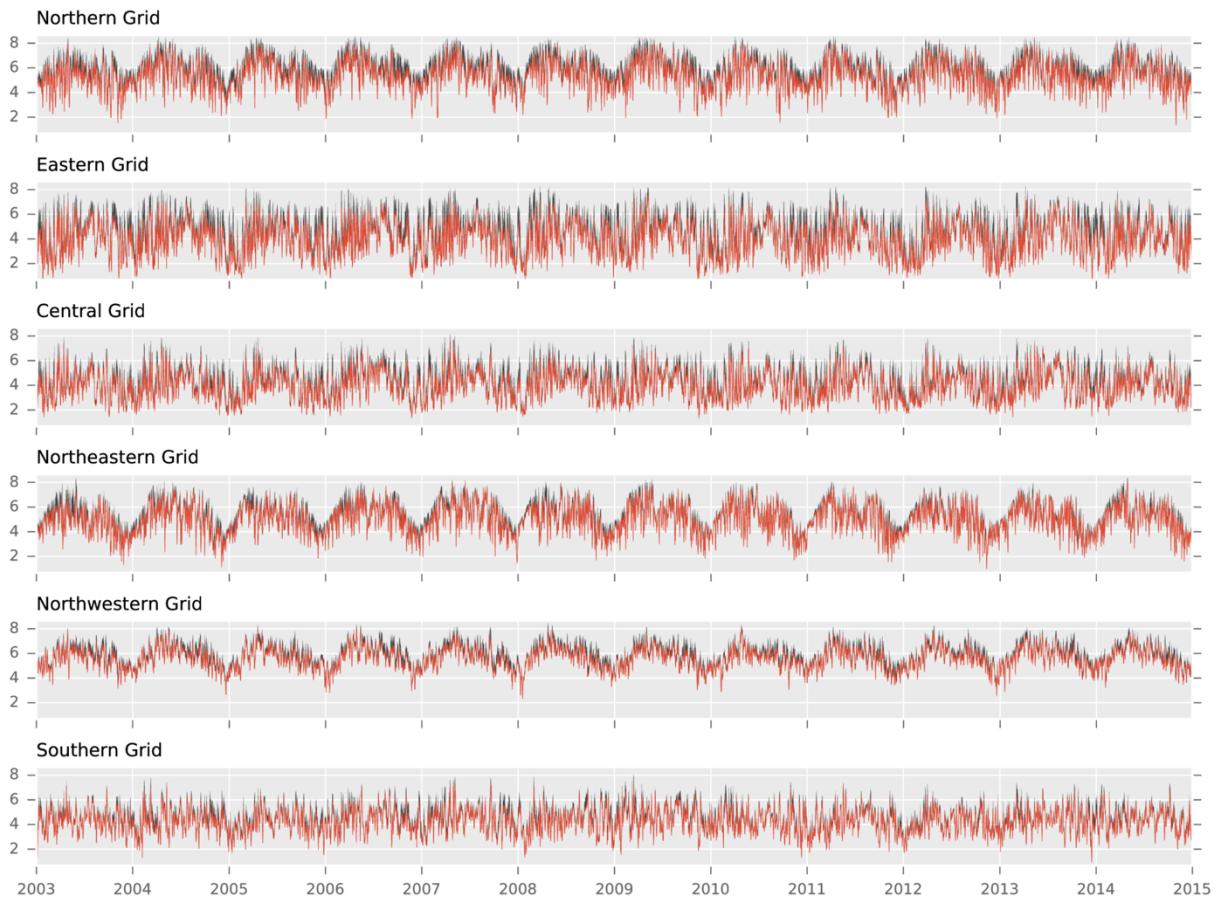


Figure S6. Time series of daily-mean point-of-array-irradiance for fixed panels averaged over each electricity grid in China. The red lines represent the All-sky scenario. The black lines represent the All-sky-without-aerosol scenario. The variability is primarily driven by clouds as can be seen by the similarity between the red and black lines. The black shaded areas indicate the aerosol impacts (allowing detection of heavy aerosol episodes by thicker shading). Units are kWh/m²/day.

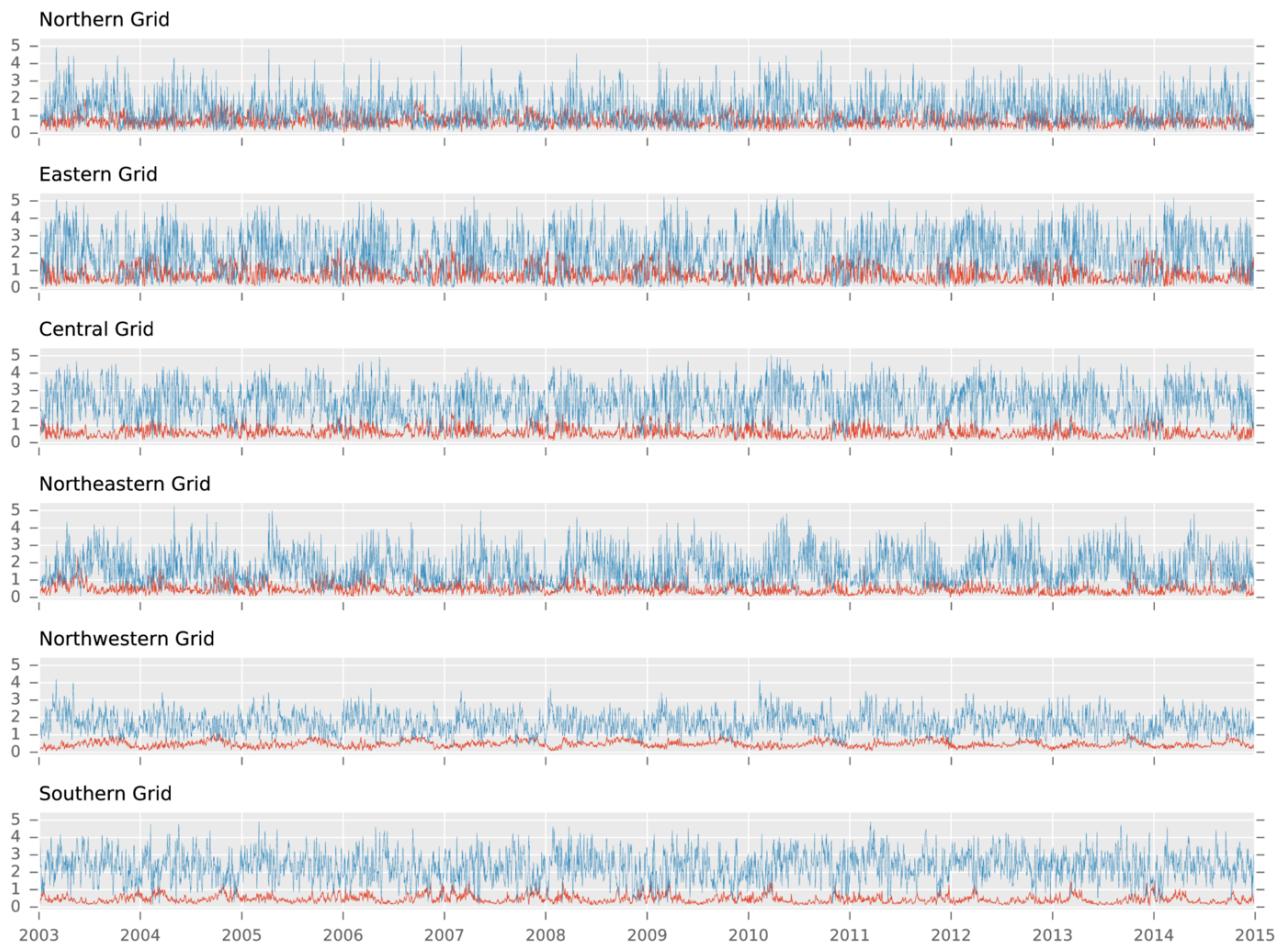


Figure S7. Time series of daily-mean point-of-array-irradiance changes due to aerosols (red) and clouds (blue) for fixed panels averaged over each electricity grid in China. The red lines represent the aerosol impacts. The blue lines represent the cloud impacts. The variability of aerosol impacts is much less than that of clouds. Units are $\text{kWh/m}^2/\text{day}$.

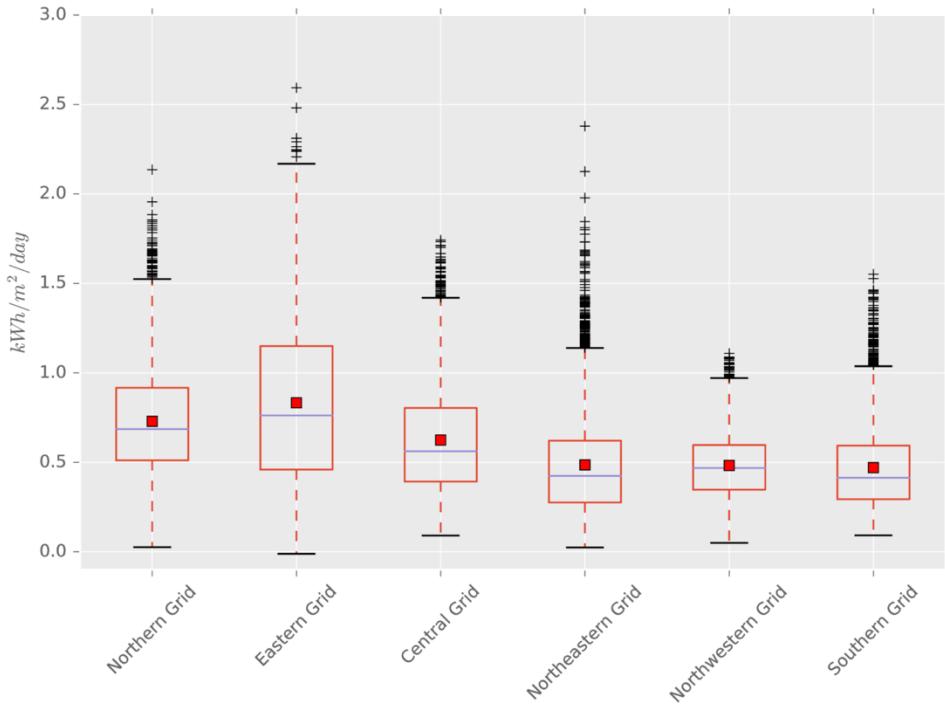


Figure S8. Boxplots of daily-mean aerosol impacts on the point-of-array-irradiance for fixed panels for each electricity grid in China. These are standard statistical boxplots. Each box extends from the first quartile (Q1) to the third quartile (Q3) values of the data, with a line at the median. Where IQR is the interquartile range (Q3-Q1), the upper whisker extends to the last datum less than $Q3 + 1.5 \times \text{IQR}$. Similarly, the lower whisker will extend to the first datum greater than $Q1 - 1.5 \times \text{IQR}$. Beyond the whiskers, data are considered outliers and are plotted as individual points. Red squares represent mean values.